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Overview of the photovoltaic technology status and perspective in Spain

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ABSTRACT

The aim of this paper is to show the current status of photovoltaic technology and the outlook for the coming years in Spain. In this way, first it gives an account of the cumulative photovoltaic power installed, the number of installations and its distribution data. Afterwards it analyses the photovoltaic implementation by assessing the significance of major projects, such as demonstration projects and photovoltaic solar farms (which use conventional and concentration photovoltaic panels). Likewise it draws attention to photovoltaic research and development activities carried out nowadays. In addition it touches on issues such as photovoltaic industry (solar silicon, cells and modules companies), new initiatives and measures of support (focusing on feed-in tariff system). Finally it lays emphasis on prospects for the coming years.

Contents

1. Introduction

Energy has been playing a determining role in economic–political–social events occurring in the world as of the second half of 20th century. It is crucial for economic growth and human development, and is fundamental to the quality of our lives. Greater or lesser availability of energy determines the economic development or stagnation of a country. Nevertheless, it was not until in the 1980s that intense legislative activity was carried out in Europe regarding energy, making the relation between the increase of industrial production, energy consumption and environmental protection more evident.

Thus, a White Paper for a Community Strategy and Action Plan [1], concerning the future of renewable energy in the European Union, was adopted by the European Commission on November 26, 1997. It defined a strategy and plan of action to promote market

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penetration of renewable energy sources, with a target of doubling their use by 2010 (from 6% of total consumption in 1996 to 12% in 2010).

At the same time, one of the characteristics of the Spanish energy system is its high degree of dependence on imports. Eighty percent of energy consumed has to come from imported sources. Spain imports approximately 64% of its coal, 99.5% of its oil, and 99.1% of its gas. Moreover, oil accounts for around 50% of Spain's primary energy consumption. Furthermore, on August 26, 2005 the Spanish government approved the new Renewable Energy Plan (*Plan de Energias Renovables*, PER) [2], which supersedes the Renewable Energy Promotion Plan, which dates back to 1999. The overall aim of the new Plan is to make it possible to achieve the target of 12% of Spain's primary energy demand being met from renewable sources by 2010, and to do so it sets more ambitious objectives in those areas that have been successfully carried out and establishes new measures to support technologies that have not yet managed to take off. The total amount of the investment of the Plan in the period 2005–2010 that has been budgeted is 23,598,641 euros. Although in the 1994–2004 period the global consumption of renewable energies grew in Spain by 2700 ktep, by the end of the year 2004 it had achieved only 28.4% of growth anticipated for those energy sources.

2. Legal framework of the interconnection to the network in Spain

With respect to legislation regarding renewable energy, in the early 1980s Law 82/1980 of December 30, was passed concerning energy conservation. However, the first PV systems connected to the electrical network in Spain were regulated by Royal Decree 2266/94, in which, for the first time, the special electrical production system was regulated. The major incentive in the electricity market came from the regulation of the sector. Following that, a new general electricity law, the Spanish Power Act 54/1997, dated November 27, came into force, in the Electrical Sector [3], establishing principles of a new model of operation based on free competition, and likewise, boosting the development of energy in special systems. The pressure of the renewable energy sector conditioned the writing and approval of a new decree that regulated, with more detail, the establishment of forms of generation.

Royal Decree 2818/1988, [4], carried out Law 54/1997 in the Electricity Sector with modifications introduced by Law 66/1997 of December 30 regarding fiscal, administrative and corporate measures, promoting the development of facilities under a special legal system through the creation of a favourable framework, without incurring discriminatory situations that could limit free competition while establishing differentiated situations for those energy systems that contribute more efficiently to the above mentioned objectives. For facilities based on renewable or waste energies, this incentive has no time limit, since their environmental benefits must be internalized and, due to their special characteristics and level of technology, their considerable cost does not allow them to compete in the free market. The incentives which are established for renewable energies are such that they will enable their contribution to the Spanish energy demand to be a minimum of 12% in the year 2010. Likewise, it provides an advantageous power rate of up to kWh produced by photovoltaic solar facilities connected to the grid. Utilities must buy photovoltaic electricity at €0.4/kWh for systems of less than 5 kW and at €0.2/kWh for systems of more than 5 kW. Two years later, the Royal Decree 1663/2000 [5] was approved, which is applied to photovoltaic installations of nominal power of not more than 100 kVA and whose connection to the distribution grid is carried out in low voltage, i.e., not higher than 1 kV. Later, in the resolution of May 31 2001, [6], the model for the type of contract and invoice for this system was established (Fig. 1). Three years later, Royal Decree 436/2004, [7], amended the previous Royal Decree 2818/1998 so as to fit into the existing general framework supporting renewable energy as set out by the Electricity Act 54/1997, which is still in force. It provides incentives for newly installed capacity of renewable energy sources in one of the two ways: (1) generators which sell their production to a distributor receive a fixed tariff that is defined as a percentage of a regulated tariff. The percentage was established on a technology-by-technology basis. The reference tariff for 2004 had a value of €0.072/kWh; (2) generators which sell their electricity on the free market receive the negotiated market price of electricity, an incentive for participating, and a premium, if eligible.

On 25 May a new Royal Decree 661/2007, [8], regulating the production of electricity in the special regime was published. It established new energy tariffs from 1 January 2008. The new Royal Decree derogates Royal Decree 436/2004, dated 12 March, which established the methodology for updating and systematising the legal and economic regime of the production of electricity in the special regime. A transitory regime has been established for certain facilities.

Also, in Spain the Electro-technical Regulation of low voltage is applicable to this sector [9], as well as particular specifications from communities and of the distributing company.

3. Figures of the photovoltaic status in Spain

In 2006, the photovoltaic industry production grew by over 40%. It reached a world-wide production volume of 2520 MWp of photovoltaic modules and became a € 12 billion business.

As with the previous years, Germany was the largest single market with 750 MW followed by Japan with 300 MW, the US with 141 MW and Spain with 97 MW. With these figures, Spain is the fourth country in the world in terms of the total photovoltaic power installed. This has come about for a number of reasons.

According to 2006 official data, Spain is the fourth country in the world with regard to PV power installed (Fig. 1) after Germany, Japan and the USA. That means that in 2006 alone there was 97 MW of PV power installed (Fig. 2) (almost five times that of 2005). Then, the cumulative PV power installed went up to 141 MW (Fig. 3) more than three times that of 2005. It is expected that at the end of 2007 it will go up to 500 MW.

On the other hand, in 2006 the numbers of PV installations went up to 9583 installations (Fig. 4). Currently there are an estimated

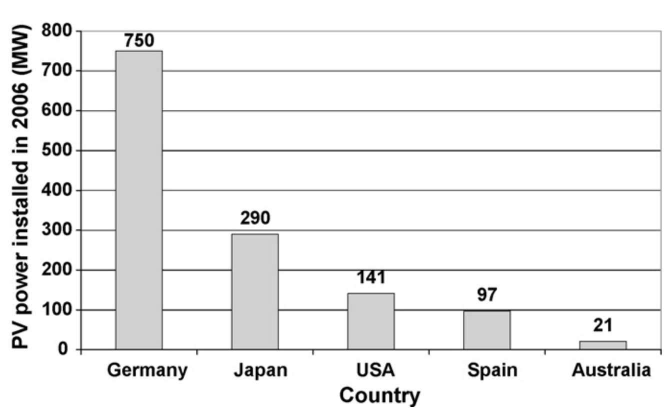


Fig. 1. PV power installed (MW) in 2006, for Germany, Japan, the USA, Spain and Australia.

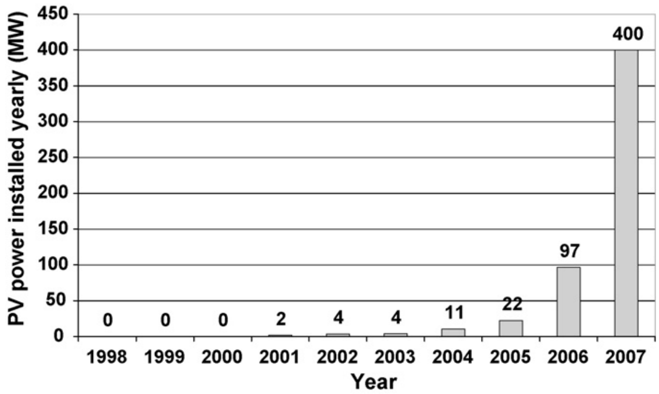


Fig. 2. PV power installed yearly (MW).

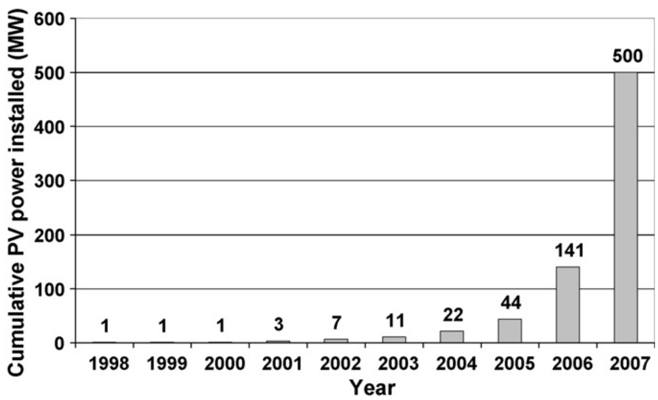


Fig. 3. Cumulative PV power installed (MW).

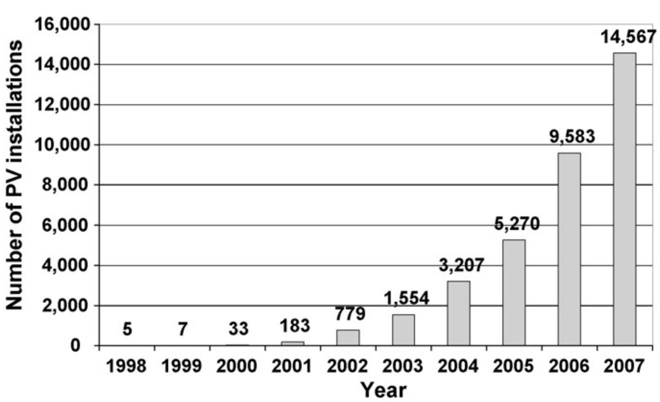


Fig. 4. Number of PV installations in Spain from 1998 to 2007.

14,567 installations which is a little more of three times that of 2005.

On the other hand the energy sold coming from PV systems reached more than 100 GWh (Fig. 5) four times that of 2005. This growth has permitted a continual lowering of costs and prices in most system components; modules instead, showed an increase in prices during 2006 due to a misalignment between the demand and the industrial capacity.

Although their estimation is difficult, it is possible to calculate approximately that the distribution (%) of the PV installations in Spain is 85% grid connected systems whereas 15% were off grid systems (Fig. 6).

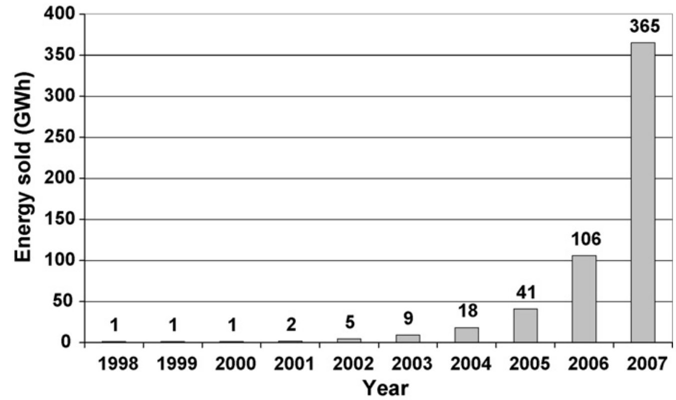


Fig. 5. Energy sold from 1998 to 2006 (GW).

4. PV implementation: highlights

Accordingly major projects relating to PV in Spain can be divided into two groups: demonstration projects and PV solar farms, called in Spain Huertas Solares (with conventional and concentration PV panels).

With respect to demonstration projects we might mention the following:

(1) *Installation in Torre Garena*: This solar PV installation (Fig. 7) is located on the roof and on the facade of the building, giving a total power of 85 kWp. The installation on the facade of the building is comprised of 948 BP 380 photovoltaic panels. The new building is located in one of the growing commercial districts of the city of Alcalá de Henares. The building's facade and roof include two different solar PV power generation plants.

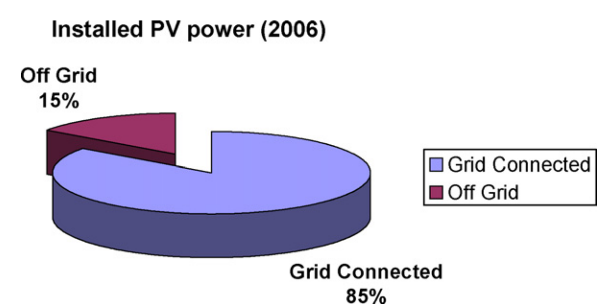


Fig. 6. Distribution (%) of the installations.



Fig. 7. PV installation in Torre Garena.

The PV installation on the facade has been built using 948 photovoltaic modules manufactured by BP solar. This installation has a total power of 75,840 Wp, representing a savings of 85 tonnes of CO_2 emissions per year. These modules have been installed at a 60° gradient to take full advantage of the available sunlight. The BP 380 modules have been manufactured using state of the art polycrystalline technology and consist of 36 cells with antireflection coating connected in series. Each panel has a nominal power of 80 Wp. The roof application incorporates an array of 93 glass–glass modules of polycrystalline solar cells each with nominal power of 100 Wp. They are located on the south facing roof with a gradient of 30°, being perfectly integrated into the building's design.

(2) *25 kW high solar concentration (250×) with tracking*: In the Telecommunications Higher Technical School of (ETSI) Engineers, Polytechnic University of Madrid (UPM) a high solar concentration (250×) has been installed, using Guascor Foton cells (Fig. 8). It was implemented with Fresnel lenses whose nominal capacity was of 25 kW. This project has been financed by IDAE.

(3) *SOLARIZATE II (Getsolarized)*: In 2006 Phase II of the project Solarizate began throughout the Spanish territory. It consists of installation of 50 PV plants in comprehensive schools and in high schools. The nominal capacity per unit is 2.5 kW. The total project (Solarizate I and II) will install 102 plants with a total power of 255 kW. The total investment will amount to €2,500,000. Every plant will have remote monitoring. The aim is to spread the culture of photovoltaic energy to comprehensive schools and in high schools and, thus, to offer didactic support (www.solarizate.org). All of them will be financed by IDAE.

(4) *1 kW high solar concentration (550×) with tracking*: In 2006 the Spanish company inspired by cooperation with the Japanese company Daido Steel installed the first HCPV system with very high efficiency three junction III–V cells in Spain. This 1 kWp demonstrator is the first HCPV system using MJ III–V cells to be installed in this country. The 550× modules have been produced by Daido Steel, which has a 28% hold of the world's efficiency record. It is mounted in a 4 m^2 laboratory tracker that is designed and produced by Inspira, also controlled by Inspira's SunDog STCU. It is the first time that this technology has been installed for long term testing outside of Japan.

(5) *Building Integrated Photovoltaics (BIPV)*: Vidursolar, company founded in 2006, has carried out recently three singular projects, using glass–glass PV modules for architectural integration: Sky light in a bus stop in Lloret de mar of 0.34 kW; Photovoltaic Parking cover in Manresa (Barcelona) of 3.91 kW and a Photovoltaic pergola in Senan (Tarragona) of 6.72 kW.



Fig. 8. 25 kW High solar concentration (250×) with tracking.

With respect to large projects they are based on Huertas Solares projects. That is to say large solar farms with many individual PV systems ranging from 5 to 100 kW. The PV systems are owned by private investors. In many of them large tracking systems up 25 kW are installed. They can be distinguished between those that use conventional PV modules and those that use concentrating PV modules.

Regarding projects with conventional PV modules in Spain are installed four of the most PV solar farms in the world:

(a) 20 MW, Hoya de Los Vincentes, Jumilla (Murcia), constructed by Luzentia, January 2008
(b) 20 MW, Beneixama (Alicant), constructed by City Solar AG, September 2007
(c) 13.8 MW Salamanca Avanzalia Solar, S.L. Kyocera Corp., September 2007
(d) 12.7 MW, Lobosillo (Murcia), constructed by Ecostream, September 2007

Regarding to concentrating PV currently in Spain there are four companies dedicated to such technology: one of them of low concentrating (Solucar Energia, SA) and three of them dedicated to high concentrating (GuascorFoton, Isofoton and Sol3G).

The Spanish company Solucar Energia, an Abengoa company, is establishing a production line for V-trough mirror concentrating systems using c-Si modules. Among their projects the more important one has been "Sevilla PV" that is the largest low-concentration PV plant in the world. The 1.2 MW Sevilla PV plant comprises 154 silicon plate heliostats of low concentration tracker (2.2×) of 376.73 ft^2 (35 m^2), with displacement on two axles. The remaining power plants will be built over the next six years. It was designed by Abengoa Solar NT. The project was carried out in collaboration with research centers (IDAE, Ciemat) and companies (Solartec, Atersa, Isofotón, Saint Gobain).

Concerning PV high concentration the Institute of Concentration Photovoltaics Systems (ISFOC) is the main vehicle for the development of CPV technologies in Spain (see Section 5). They are executing a number of power plants (up to 3 MW in total) incorporating different concentrator technologies which are becoming available in the market. The 3 MW CPV pilot plant program has been divided into two tenders. The first one of 1.7 MW phase of CPV pilot plants has been awarded to Isofoton (700 kW), SolFocus (500 kW), and Concentrix (500 kW). And the second phase, 1.3 MW tender, has been awarded to the following companies: 300 kW to Concentración Solar La Mancha (Spain); 300 kW to Emcore (USA); 300 kW to Arima Eco (Taiwan) and 400 kW to Sol3G (Spain).

In addition other companies have installed or are under construction different plants. In this way, for example, Guascor Foton has installed 3.5 MW CPV Power Plants in Villafranca (Navarra), 950 kW Talayuela (Cáceres) y Moratalla (Murcia). And Abengoa Solar has the following current projects:

Hicon PV-1000×:	Developed in collaboration with the USA. It is focused on the development of high-concentration systems
Fresnel PV-5×:	Is based on the Fresnel theory of optic concentration of sun rays up to 10×
CAC-30×:	Development of medium concentration technology

Natama:	It is project supported by the 6th European Union Framework Program that has the purpose of developing processes for the synthesis, analysis, and characterization of thin titanium layers by means of techniques and nano-engineering, and the evolution of its possible application of results achieved on several areas of development, under an analysis of different perspectives, with special interest on photovoltaic generation
Sevilla PV:	Development of a low concentration system photovoltaic system with V. Trough technology and Silico cells. The project is carried out in collaboration with research centers (IDAE, Ciemat) and companies (Solartec, Atersa, Isofotón, Saint Gobain)
Multionda PV 2:	Improvement on the photovoltaics efficiency through the development of multistring investors in order to reduce losses by mismatch. The project is made in collaboration with companies (Inabensa, Greenpower)
Hicon PV Gen 2:	Development of the 2nd photovoltaics dish generation The project is carried out in collaboration with research centers (Isfoc)
CPV:	Development of a high concentration photovoltaic system. The project is carried out in collaboration with research centers ((Universidad Complutense de Madrid, Universidad Politécnica de Cataluña, Cener, Ciemat, ESI Sevilla)

5. R&D (research and development) in Spain

R&D activities in Spain are carried out by both the research centres and universities and PV industry. They develop R + D activities through open contests. What is more, they can access public funds intended for R + D + I, to finance their activities, and which are responsible for their execution.

The main lines of activity can be summarized as follows:

- New thin-film PV materials.
- Production technologies thinner cells and improvements in efficiency.
- Deposited silicon PV devices.
- New materials
- PV solar cells, modules and fields.
- Concentration technologies
- New prototypes of PV components.
- PV modules and inverters connected to the grids for integration in buildings.
- Stand-alone PV Systems for professional use and developing countries.
- Engineering and evaluation of PV power plants.

Executive agents existing in Spain are varied. Among these are Public R + D Centres:

- Universities (www.mec.es), regulated by the University Reform Act of 25 August 1983.

  One of the most important is the Instituto de Energia Solar, IES, (Institute of Solar Energy). Belonging to Polytechnic University of Madrid, it is Spain's leading research centre in photovoltaic and one of the most innovative in the world.
- Public Research Organisms (OPIs) acknowledged as such by the Science Act and, in general, any R + D centre dependent on public administrations.

  There are three important organisms:

  - CENER (National Renewable Energies Centre): This is an industrial technology centre dedicated exclusively to Renewable Energies. Its activities include providing support for R&D and innovation in firms by delivering technological services, running R&D projects under contract and in a consulting capacity; using research and development to develop production technology and exploit energy sources; and facilitating maximum penetration of renewable energies in the energy system by generating the necessary tools and services to provide solutions to technical problems and relational difficulties between the various agents within the systems.
  - CIEMAT: Its purpose is to reduce costs, and increase performance and reliability of photovoltaic (PV) modules, components and systems, and carry out research in new materials for solar cells and in new concepts for electricity generation using the sun as the primary energy resource, through the following objectives:
    - To increase knowledge of amorphous and microcrystalline silicon and chalcopyrite thin-film materials for fabrication of low-cost PV modules with better performance and low material consumption.
    - To develop high-efficiency PV cells based on chalcopyrite structure materials, and to develop stable microcrystalline or amorphous silicon p-i-n cells and heterojunction mono or bifacials cells crystalline silicon wafers.
    - To become a National and European centre of reference for measurement, testing, calibration and development of standards in the field of PV solar energy.
    - To perform applications for PV integration in buildings.
    - To make theoretical models and experimental studies on the behaviour of solar cells of different technologies.
    - To make programs for simulation, sizing and estimation of PV plants.
    - To Increase performance and reliability of PV components (accumulators, regulators, converters, lamps, inverters, water pumpings, etc.) in cooperation with the manufacturers.
    - To participate in the engineering and evaluation of both stand-alone and grid-connected PV power plants, especially in demonstration projects.
    - To develop new ideas, devices and prototypes by means of I + D projects.
    - To actively participate in national plans for renewable energy promotion.
    - To co-operate with developing countries to promote the use of PV systems for electricity supply.
  - INSTITUTO DE TECNOLOGÍA MICROELECTRÓNICA

Other R + D Centres dependent on General State Administration, Regional Governments or local Governments (www.map.es).

In addition, a new institute for CPV (concentrating photovoltaic) systems, ISFOC, Instituto de Sistemas Fotovoltaicos de Concentración S.A. (institute of PV concentration systems) has been created in Spain (20 M€ + 0.9 M€/year). It is the result of the R&D plan promoted by the Department of Education and Science from the Castilla La Mancha Government and the Institute of Solar Energy (ISE) from the Universidad Politecnica de Madrid. The headquarters, laboratories and some of the ISFOC pilot photovoltaic plants are being built in Puertollano, where all the Institute activities will be coordinated. Establishing in Castilla La Mancha the main vehicle for the development of CPV technologies is our

chief goal. In order to generate key knowledge on this technology, ISFOC is executing a number of power plants (up to 3 MW in total) incorporating different concentrator technologies which are becoming available in the market. ISFOC has become a national and world reference in CPV and with the infrastructure installed after the two-year establishment period, ambitious R&D projects will be undertaken.

Currently, they are executing a number of power plants (up to 3 MW in total) incorporating different concentrator technologies which are becoming available in the market. The 3 MW CPV pilot plant program has been divided into two tenders. The first one of 1.7 MW phase of CPV pilot plants have been awarded to Isofoton (700 kW), SolFocus (500 kW), and Concentrix (500 kW). And the second phase, 1.3 MW tender, has been awarded to the following companies: 300 kW to Concentración Solar La Mancha (Spain); 300 kW to Emcore (USA); 300 kW to Arima Eco (Taiwan) and 400 kW to Sol3G (Spain).

The R&D Spanish National Plan (2004–2007) has no specific R&D Program in Photovoltaics. Therefore the Energy National Program takes part in the National R&D Plan (2004–2007). In this program it is possible to distinguish different areas. One of them is the Area of Renewable Energies and New Technologies; Renewable Energies and New Technologies which are formed by:

- Wind energy
- Photovoltaic energy
- Solar thermal
- Biomass
- Hydrogen and fuel cells
- Others (tidal energy, geo-energy...)

The targets of the R&D actions are:

- *PV materials*: R&D and characterisation of costless PV materials, in the field of solar grade Si raw materials, and thin films devices.
- *PV cells*: Improved technologies and optimization of PV cells manufacturing processes, modernization of manufacturing systems aimed at reducing costs. New concepts that consume less material and take advantage of the spectrum.
- *PV modules*: R&D and innovation of PV modules in the field of manufacture and qualification, building integration, concentration system and new concepts.
- *PV systems*: R&D to improve the BOS, development of new applications and aspects of the design, solar tracking, monitoring and remote management and reliability of the service.
- *Grid connection*: R&D of technologies to improve the grid matching and security in the connections to the electricity networks. Development of new regulations and qualification tools for on-grid installations.

On one hand, the strengths of the Spanish PV-R&D sector are:

- High level of R&D.
- High own technology.
- 30% annual growth in manufacture.
- 50% annual growth in facilities and related industries.
- Export of 85% of the production of panels to more than 50 countries (24% of the EU production in 2005).

On the other hand, the following weakness and obstacles can be found in the SPANISH R&D-PV SECTOR the

- Lack of funds directly targeted to R&D-PV.
- Fragmentation of research efforts.
- Poor technology transfer from R&D to the industry.
- Need for a network of excellence/reference centres on R&D-PV
- Lack of available trained R&D-PV labour force

5.1. Public budgets for market stimulation, demonstration/field test programmes and R&D

Public budgets come from three different sources:

(1) *European Commission*: Photovoltaic R&D activities receiving support from the European Commission can be divided into short to medium-term and medium to long-term, and are managed by DG TREN and DG RTD respectively. The following PV projects, where leadership is carried out by Spanish entities, are currently ongoing in the Sixth Framework Programme (FP6):

    Full Title: A new wave making more efficient use of the solar spectrum (FULL SPECTRUM)
    Website: http://www.fullspectrum-eu.org/
    Coordinator: A. Luque, Universidad Politécnica de Madrid, Spain
    Instrument: Integrated Project
    EC contribution: 8.3 M€
    Starting date: 01/11/2003
    Duration: 60 months

    The FULL SPECTRUM Project aims to further develop concepts that are already scientifically proven but not yet developed, and by trying to prove new ones in search of a breakthrough for PV technology, notably the development of:
    - III–V multi-junction cells towards 40% efficiency
    - Solar thermo-photovoltaic converters
    - Intermediate band materials and cells
    - Molecular-based concepts for full utilization of the solar spectrum
    - Manufacturing technologies for novel concepts

    Full Title: High concentration PV power system (HICONPV)
    Website: http://www.solucar.es/hiconpv/
    Coordinator: V. Fernández Quero, Solucar, Spain
    Instrument: STREP
    EC contribution: 2.7 M€
    Starting date: 01/01/2004
    Duration: 36 months

    HICONPV aims to develop, set up and test a new cost-effective high concentration PV system with a concentration factor of 1000. The cost goal for the proposed type of system is €1/Wp until 2015. The most challenging task will be the development of a high-efficiency 2 kWp III–V receiver with a module area of about 100 cm^2.

(2) National: Research in Spain is mainly funded by the Ministry of Education and Science (MEC) and by the Ministry of Science and Technology (MCyT). The MEC activities are aimed at developing all disciplines of science, stimulating and funding research at universities and research institutes. MEC manages funding through the National Plans of Research, Development and Technological Innovation (PN I + D + I) which, with a duration of four years, set priorities for annual, peer-reviewed competitive calls. The design of priorities and programmes is carried out by the Ministry in the framework of national interests, taking into consideration the EU RTD programmes.

(3) Regional: Spain has 17 autonomous communities. In many of them there is a public budget for R&D.

6. PV industry

6.1. Production of feedstocks, ingots and wafers

In 2008, in Spain there will be three companies dedicated to feedstock material and Wafers: Silicio Solar S.L., Silicio Energia and DC Wafers. On one hand, Silicio Solar S.L. is a company integrated into the holding formed by Pilar JSC, Lionberg & Co. Ltd. y Hardesty Ltd. On the other hand Silicio Energia is a company jointly held by Isofoton, leading Spanish technological company in Solar Energy, Endesa, leading Spanish utility, Junta de Andalucia, regional Government of Andalucia Spain and different Andalucian Financial Institutions. Silicio Energia aims to build advanced and efficient polysilicon production facility in Spain, with the objective of supplying this material to the booming Photovoltaic Spanish industry. The polysilicon plant is in Los Barrios (Cadiz) and will become operational in 2009. The plant is expected to cost €250 million and yield 2500 tonnes of polysilicon per year, equivalent to 250 MW of PV modules.

And finally DC Wafers will produce polycristaline silicon wafers for the PV industry of different sizes and thickness levels. It will gradually begin their production half way into 2008, gaining complete production capacities at the end of 2008. DC Wafers' initial production capacity will be 13 million wafers per year.

6.2. Production of photovoltaic cells and modules

6.2.1. Solar cells

In 2006, in Spain there were three companies dedicated to PV cells: BP Solar Spain, Guascor Foton and Isofoton although all this production was for use by the same companies. BP Solar Spain (with Saturn 7 high efficiency cell) and Isofoton (with Si monocristalline pseusquare shape cells) have manufacturer conventional cells, whereas Guascor Foton is dedicated to manufacturing high concentration silicon photovoltaic cells (400× high efficiency cells).

6.3. PV modules

In 2006, in Spain there were 12 companies dedicated to photovoltaic modules (in alphabet order):

Atersa, BP solar, Cuantum Solar, Gamesa Solar, Gruposolar, Guascor Foton, Isofoton, Pevafersa, Siliken, Solaria, Sol3G and Vidur Solar: Solaria is currently building a new factory in Spain, which will be completed by the end of 2006. Its 100 MW capacity will be increased to 500 MW over the next three years.

Manufacturers can be grouped into four types: those that manufacture conventional PV modules (Atersa, BP solar, Cuantum Solar, Gamesa Solar, Gruposolar, Isofoton, Pevafersa, Siliken and Solaria); those that manufacture concentrating modules (Solucar Energia SA, Guascor Foton, Sol3G and Isofoton); those where the characteristics of this product allow it to be used in a myriad of applications where functionality and beauty are needed (Vidur Solar) and those that manufacture amorphous silicon thin film photovoltaic modules (T-Solar Global).

Vidursolar, company founded in 2006, is dedicated to wall-mounted sunshades, façade coverings, curtain walls, flat glass coverings and pergolas.

Regarding concentrating PV currently in Spain there are four companies dedicated to such technology: one of them of low concentration (Solucar Energia, SA) and three of them dedicated to high concentration (GuascorFoton, Isofoton and Sol3G).

The Spanish company Solucar Energia, an Abengoa company, is establishing a production line for V-through mirror concentrating systems using c-Si modules. Guascor Foton whose production is based exclusively on 400× high concentration is based on silicon. Isofoton are co-operating with IES-UPM to develop a concentrating system (Type IIIB2, C $\sim$1000) with III–V high efficiency cells. And Sol3G has just inaugurated a new factory of 800 m^2 in Terrassa with an annual productive capacity of 5 MW. The future plans of the company are to increase the production capacity up to 10 MW/year for the end of 2008 and to maintain an intense work of investigation and development to continue leading the world-wide market of HCPV systems.

And finally, it is noticed to mentioned T-Solar Global that is the only Spanish company that is going to begin the production of large area amorphous silicon thin film photovoltaic modules. This company is located at Orense (Galizia). The panels to be manufactured by the new plant will be 5.7 m^2 in size. They are going to use a system that results in production costs 2.5 times lower than normal. A total of €75 million will be invested in the construction of the plant, which is scheduled to start in mid-April of 2007. The site is expected to register annual turnover of more than €100 million. The plant is expected to be fully operational at the end of 2008.

Table 1 shows the production and production capacity for PV Spanish manufacturers in 2006. The data were obtained directly from manufacturers. Grupo Solar did not wish to provide information relating to their production.

According to different forecasts it is hoped that cell and module production will be increased in the coming years.

7. New initiatives

On the one hand, from 27 September 2006 the Royal Decree 314/2006, Technical Building Code, regulates the incorporation of PV energy in buildings, Section HE5. It forces the installation of PV on new large buildings, such as offices, hospitals, etc. Its application is currently obligatory. It establishes the demands to be met by buildings. In addition it enforces the installation of PV on new large buildings, such as offices, government buildings, hospitals, etc. in accordance with limits.

As well the minimum capacity required will depend on the climatic zone (the minimum photovoltaic power to be installed is determined by the climatic zone), floor area and kind of building use.

The peak capacity P to be installed is defined by the formula P (kW) = $C(AS+B)$, where C is the defined coefficient for each climatic zone; A and B are the coefficients defined for each kind of use and S is the floor area built in square metres. The minimum PV to be installed will be 6.25 kW.

8. PV Support measures

Important aspects in Spain are the PV support measures. On the one hand, it is noticeable to mention that there are no direct capital subsidies because it is easy to find soft loans in private banking. So in Spain direct subsidies for grid connected plants are not necessary.

On 25 May a new Royal Decree 661/2007, [6], regulating the production of electricity in the special regime was published. It established new energy tariffs from 1 January 2008. The new Royal Decree derogates Royal Decree 436/2004, dated 12 March, which established the methodology for updating and systematising the legal and economic regime of the production of electricity in the special regime. A transitory regime has been established for certain facilities.

The main characteristics of Royal Decree 661/2007 are, in general, the following:

Table 1
Production and production capacity information for the year for each manufacturer

Cell/module manufacturer	Technology (sc-Si, mc-Si, a-Si, CdTe)	Total Production (MW)			Maximum production capacity (MW/year)		
		Cell	Module	Concentrators	Cell	Module	Concentrators
Atersa, BP	Sc-Si		11.9			21	
	mc-Si		0.7			1	
BP Solar	Saturn 7, Sc-Si		50		55		
Cuantum Solar			0.4			3	
Gamesa Solar	mc-Si		3.7			3.7	
Grupo Solar			0				
Guascor Foton			0	2			60
Isofotón	mc-Si	61	61		130	130	
Pevafersa	mc-Si, Sc-Si		4			8	
Siliken			15			27	
Total		61	146.7	2	185	185.7	60

(a) Date of entry into force: Friday, 1 June 2007.
(b) Derogation: it derogates Royal Decree 436/2004, dated 12 March, which established the methodology for updating and systematising the legal and economic regime of the production of electricity in the special regime.
(c) It establishes a Feed-in-tariff system for the 25 years, from 2007. The tariff' system is shown in Table 2.

The tariffs will be updated every year according to the CPI until 2012.

(d) Transitory regime: a transitory regime has been established for certain facilities which, in short, consists of the following:

Any facilities in possession of a certificate for the definitive start up of service before 1 January 2008 which opted, before 1 January 2009, to transfer the electricity to the system whilst receiving a regulated tariff in exchange may continue to be covered by the regulation established in Royal Decree 436/2004 throughout the remaining lifetime of the facility.

Any facilities in possession of a certificate for the definitive start up of service before 1 January 2008 which opted, before 1 January 2009, to sell energy on the market may continue to be covered by the regulation established in Royal Decree 436/2004 until 31 December 2012.

Facilities utilizing solar energy as raw material do not fall within the scope of application of the preceding sections and the new Royal Decree shall be automatically applicable to them.

(e) Compensatory regime: a system similar to that contemplated in Royal Decree 436/2004, dated 12 March, is to be maintained which will establish that the holder of the facility may choose, for periods of no less than one year, one of the following two options:
- To transfer electricity to the system through the transportation and distribution network, receiving a regulated tariff in exchange, which will be unique to each programme period. The said regulated tariff consists of a fixed amount, expressed in cents of a euro per kilowatt, which is determined according to the category, group and subgroup to which the facility belongs, as well as its power output.
- To sell the said energy directly on the daily market, on the futures market or through a bilateral agreement, receiving in this case the price traded on the market plus a premium. The said premium, expressed similarly in cents of a euro per kilowatt, consists of an amount in addition to the price which results from the sale on the market of the energy produced. In the last case, a new feature was introduced for certain technologies, upper and lower limits on the total of the hourly price on the daily market, plus a reference premium, so that the premium to be received in each hour may be capped according to the said values. This new system aims, on the one hand, to protect the promoter when the income derived from the market price is excessively low and, on the other hand, to eliminate the premium when the market price is high enough to guarantee that costs are covered, eliminating alleged irregularities in the compensation of technologies, the costs of which are not directly linked to the price of oil on international markets.

Another important topic for this Royal Decree is the guarantees for processing new applications: those requesting new production facilities in the special regime must present a guarantee for an amount equivalent to €500 per kilowatt (kW) for the photovoltaic facilities or €20/kW for all other facilities. The said guarantees must be presented prior to the request for access to the relevant network (of transportation or distribution). The guarantee will be cancelled when the requesting party obtains the certificate for the start up of the facility.

Table 2
Feed-in tariff system in Spain according to Royal Decree 661/2007

Power (kW)	Tariff (cent €/kWh)
Installations <100 kW	44.0381 (for the first 25 years) 35.2305 (from then on)
Installations <100 kW	41.7500 (for the first 25 years) 33.4000 (from then on)
100 kW < Installations < 100 kW	22.9764 (for the first 25 years) 18.3811 (from then on)

Alternatively, in order to guarantee a more efficient use of the plants and to encourage their development, the new Royal Decree permits hybridization (for example, that a thermoelectric solar plant use biomass when there is no sun or a biomass energy plant burn forest residues when supplies are low).

Royal Decree 661/2007 foresees that a new general review of the compensatory scheme shall be carried out in 2010 and then every four years from this date in accordance with the fulfilment of the energy targets. The 2010 update of the tariffs, premiums, complements and upper and lower limits defined in the new Royal Decree shall take into account the degree to which the Renewable Energy Plan in force and the Spanish Energy Saving and Efficiency Strategy have been satisfied, as well as the new targets to be included in the subsequent Renewable Energy Plan in the 2011–2020 period (the elaboration of which is forecast to commence in 2008).

Table 3
Feed-in tariff system in Spain according to draft of new Royal Decree

Type	Power	Tariff (cent €/kWh)
Type I	$P \leq 20$ kW	44.00
	20 kW $< P \leq 200$ kW	39.00
	$P > 200$ kW	33.00
Type II		31.00

In short, the new Royal Decree intends to make it possible to achieve, by 2010, the national target contained in Directive 2001/77/CE of the European Parliament and Council, dated 27 September 2001, concerning the promotion of electricity from renewable energy sources in the domestic electricity market, to the extent that at least 29.4% of gross electricity consumption in 2010 should derive from renewable energy sources.

However a new project is being drawn up. It is probably that two types of installations on building (Type I) and on land (Type II), are going to be distinguished. Also new objectives will be fixed for installations Type I: 200 MW and for installations Type II: 600 MW.

In addition the new tariffs presented in that draw up are shown in Table 3.

Then, in 2008, and if that new Royal Decree is published, three different tariffs will exist because three regulations will be run simultaneously.

(A) Tariffs for those installations registered before 29/09/2008
(B) Tariffs for those installations registered between 29/09/2008–31/12/2009
(C) Tariffs for those installations registered from 01/01/2010

9. Prospects of the PV use in Spain

The target about photovoltaic in Spain has been changed. Firstly, the Plan for Renewable Energy (2000–2005) puts as objective 150 MW. Later, the Plan for Renewable Energy (2005–2010) modified that aim and put it up 400 MW in 2010. Now it is foreseen that the next year a new Royal Decree is endorsed going up the limit up to 1200 MW until 2010.

In order to raise the PV installations in Spain currently two aspects are being run. On the one hand the 314/2006 Royal Decree, Technical Building Code (TBC), enforces the installation of PV on new large buildings. The aim of this Decree is to stimulate integrating PV into buildings. The PV system should be a part of the building design like any other installation and has to be a part of the building permit granted by the local administration.

On the other hand the attractiveness of the Spanish PV market is being based on providing a feed-in tariff. Until now the 661/2007 Royal Decree, published on 25 May, 2007 has been attractive even for large-scale PV applications. Even though it will be substituted by another soon. From the draft it is most likely seen that that from feed-in tariff system's point of view two types of installations (on building and on land) are going to be distinguished. Hence, new objectives will be set up that place more emphasis on PV building installations than PV land installations. This last aspect represents a change in the approach as has been practiced until now.

As result of the PV cumulative installed until now it is forecasted in the coming years a increasing in PV module production capacity. What is more, as of 2008 there will be new Spanish companies dedicated to producing solar silicon, PV module and cells productions.

So, in conclusion, the development of alternatively concentrating photovoltaic systems in Spain will go ahead in accordance with the interest expressed by the industry and researchers. It is expected that new PV concentration plants will be installed. At this point, it seems that the companies dedicated to this technology will consolidate their market.

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[5] Royal Decree 1663/2000, dated September 29th, on the connection of photovoltaic installations to the low voltage network.
[6] Resolution of 31 of May of 2001, the main directorate of power policy and mines, by that they settle down contract model type and model of invoice stops connected photovoltaic solar facilities to the network of low tension.
[7] Royal Decree 436/2004, of 12 of March, by that the methodology settles down for update and systematization of the legal and economic regime of activity of production of electrical energy in special regime.
[8] Royal Decree 661/2007, of 12 of March, regulating the production of electricity in the special regime.
[9] Spanish Low Voltage Electro-technical Regulations (Royal Decree. 842/2002, of 2 August) and their complementary technical instructions.